ERRATA.

On pp. 28, 32, 40, 53, statements are made with reference to the supposed acceleration of the revolving movement towards the light. It appears from the observations given in 'The Power of Movement in Plants,' p. 451, that these conclusions were drawn from insufficient observations, and are erroneous.

If we take hold of a growing sapling, we can of course bend it to all sides in succession, so as to make the tip describe a circle, like that performed by the summit of a spontaneously revolving plant. By this movement the sapling is not in the least twisted round its own axis. I mention this because if a black point be painted on the bark, on the side which is uppermost when the sapling is bent towards the holder's body, as the circle is described, the black point gradually turns round and sinks to the lower side, and comes up again when the circle is completed; and this gives the false appearance of twisting, which, in the case of spontaneously revolving plants, deceived me for a time. The appearance is the more deceitful because the axes of nearly all twining-plants are really twisted; and they are twisted in the same direction with the spontaneous revolving movement. To give an instance, the internode of the Hop of which the history has been recorded, was at first, as could be seen by the ridges on its surface, not in the least twisted; but when, after the 37th revolution, it had grown 9 inches long, and its revolving movement had ceased, it had become twisted three times round its own axis, in the line of the course of the sun; on the other hand, the common Convolvulus, which revolves in an opposite course to the Hop, becomes twisted in an opposite direction.

Hence it is not surprising that Hugo von Mohl (p. 105, 108, &c.) thought that the twisting of the axis caused the revolving movement; but it is not

generally and strongly with twining-plants than with other plants, that there must be some connexion between the capacity for twining and axial twisting. The stem probably gains rigidity by being twisted (on the same principle that a much twisted rope is stiffer than a slackly twisted one), and is thus indirectly benefited so as to be enabled to pass over inequalities in its spiral ascent, and to carry its own weight when allowed to revolve freely.[*]

I have alluded to the twisting which necessarily follows on mechanical principles from the spiral ascent of a stem, namely, one twist for each spire completed. This was well shown by painting straight lines on living stems, and then allowing them to twine; but, as I shall have to recur to this subject under Tendrils, it may be here passed over.

The revolving movement of a twining plant has been compared with that of the tip of a sapling, moved round and round by the hand held some way down the stem; but there is one important difference. The upper part of the sapling when thus moved

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five were observed to be twisted in an opposite direction. The Spanish chestnut is often much twisted: there is an interesting article on this subject in the 'Scottish Farmer,' 1865, p. 833.

[*] It is well known that the stems of many plants occasionally become spirally twisted in a monstrous manner; and after my paper was read before the Linnean Society, Dr. Maxwell Masters remarked to me in a letter that "some of these cases, if not all, are dependent upon some obstacle or resistance to their upward growth." This conclusion agrees with what I have said about the twisting of stems, which have twined round rugged supports; but does not preclude the twisting being of service to the plant by giving greater rigidity to the stem.

but moved in a rather irregular course during the day to the light, and from the light at night. The petioles, when well rubbed, showed no power of curving, nor could I see that they ever clasped any neighbouring object. We have seen in this genus a gradation from species such as *T. tricolorum*, which have extremely sensitive petioles, and internodes which rapidly revolve and spirally twine up a support, to other species such as *T. elegans* and *T. tuberosum*, the petioles of which are much less sensitive, and the internodes of which have very feeble revolving powers and cannot spirally twine round a support, to this last species, which has entirely lost or never acquired these faculties. From the general character of the genus, the loss of power seems the more probable alternative.

In the present species, in *T. elegans*, and probably in others, the flower-peduncle, as soon as the seed-capsule begins to swell, spontaneously bends abruptly downwards and becomes somewhat convoluted. If a stick stands in the way, it is to a certain extent clasped; but, as far as I have been able to observe, this clasping movement is independent of the stimulus from contact.

ANTIRRHINEÆ.—In this tribe (Lindley) of the Scrophulariaceæ, at least four of the seven included genera have leaf-climbing species.

Maurandia Barclayana.—A thin, slightly bowed shoot made two revolutions, following the sun, each in 3 hrs. 17 min.; on the previous day this same shoot revolved in an opposite direction. The shoots do not twine spirally, but climb excellently by the aid of

which alone has the power of revolving; so that they could be brought only by accident into contact with any neighbouring object. Nevertheless (and this is the remarkable fact) the flower-peduncles, whilst young, exhibit feeble revolving powers, and are slightly sensitive to a touch. Having selected some stems which had firmly clasped a stick by their petioles, and having placed a bell-glass over them, I traced the movements of the young flower-peduncles. The tracing generally formed a short and extremely irregular line, with little loops in its course. A young peduncle 1½ inch in length was carefully observed during a whole day, and it made four and a half narrow, vertical, irregular, and short ellipses—each at an average rate of about 2 hrs. 25 m. An adjoining peduncle described during the same time similar, though fewer, ellipses. As the plant had occupied for some time exactly the same position, these movements could not be attributed to any change in the action of the light. Peduncles, old enough for the coloured petals to be just visible, do not move. With respect to irritability,* I rubbed two young peduncles (1½ inch in length) a few times very lightly with a thin twig; one was rubbed on the upper, and the other on the lower side, and they became in between 4 hrs. and 5 hrs. distinctly bowed towards

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* It appears from A. Kerner's interesting observations, that the flower-peduncles of a large number or plants are irritable, and bend when they are rubbed or shaken: Die Schutzmittel des Pollens, 1873, p. 34.

sensitive; some of the later ones were so, but only towards their extremities, which were thus enabled to clasp sticks. This could be of no service to the plant, as these leaves rose from the ground; but it showed what the future character of the plant would have been, had it grown tall enough to climb. The tip of one of these basal leaves, whilst young, described in 1 hr. 36 m. a narrow ellipse, open at one end, and exactly three inches in length; a second ellipse was broader, more irregular, and shorter, viz., only 2½ inches in length, and was completed in 2 hrs. 2 m. From the analogy of *Fumaria* and *Corydalis*, I have no doubt that the internodes of Adlumia have the power of revolving.

Corydalis claviculata.—This plant is interesting from being in a condition so exactly intermediate between a leaf-climber and a tendril-bearer, that it might have been described under either head; but, for reasons hereafter assigned, it has been classed amongst tendril-bearers.

Besides the plants already described, *Bignonia unguis* and its close allies, though aided by tendrils, have clasping petioles. According to Mohl (p. 40), *Cocculus Japonicus* (one of the Menispermaceæ) and a fern, the *Ophioglossum Japonicum* (p. 39), climb by their leaf-stalks.

We now come to a small section of plants which climb by means of the produced midribs or tips of their leaves.

LILIACEÆ.—*Gloriosa Plantii.*—The stem of a half-grown plant continually moved, generally describing an irregular spire, but sometimes oval figures with the longer axes directed in different lines. It either followed the sun, or moved in an opposite course, and sometimes stood still before reversing its direction. One oval was completed in 3 hrs. 40 m.; of two horseshoe-shaped figures, one was completed in 4 hrs. 35 m. and the other in 3 hrs. The shoots, in their movements, reached points between four and five inches asunder. The young leaves, when first developed, stand up nearly vertically; but by the growth of the axis, and by the spontaneous bending down of the terminal half of the leaf, they soon become much inclined, and ultimately horizontal. The end of the leaf forms a narrow, ribbon-like, thickened projection, which at first is nearly straight, but by the time the leaf gets into an inclined position, the end bends downwards into a well-formed hook. This hook is now strong and rigid enough to catch any object, and, when caught, to anchor the plant and stop the revolving movement. Its inner surface is sensitive, but not in nearly so high a degree as that of the many before-described petioles; for a loop of string, weighing 1·64 grain, produced no effect. When the hook has caught a thin twig or even a rigid fibre, the point may be perceived in from 1 hr. to 3 hrs. to have curled a little inwards; and, under favourable circumstances, it curls round and permanently seizes an object in from 8 hrs. to 10 hrs.

stiff petioles of *Clematis flammula* are sensitive to even much less weight if spread over a wide surface. The petioles always bend towards the side which is pressed or touched, at different rates in different species, sometimes within a few minutes, but generally after a much longer period. After temporary contact with any object, the petiole continues to bend for a considerable time; afterwards it slowly becomes straight again, and can then re-act. A petiole excited by an extremely slight weight sometimes bends a little, and then becomes accustomed to the stimulus, and either bends no more or becomes straight again, the weight still remaining suspended. Petioles which have clasped an object for some little time cannot recover their original position. After remaining clasped for two or three days, they generally increase much in thickness either throughout their whole diameter or on one side alone; they subsequently become stronger and more woody, sometimes to a wonderful degree; and in some cases they acquire an internal structure like that of the stem or axis.

The young internodes of the *Lophospermum* as well as the petioles are sensitive to a touch, and by their combined movement seize an object. The flower-peduncles of the *Maurandia semperflorens* revolve spontaneously and are sensitive to a touch, yet are not used for climbing. The leaves of at least two, and probably of most, of the species of *Clematis*, of *Fumaria* and *Adlumia*, spontaneously curve from side to side, like the internodes, and are thus better adapted to

rather thick stick, and its petioles were brought into contact with it, these curved round the stick, showing that they have some degree of irritability. The petioles also exhibit a slight degree of spontaneous movement; for in one case they certainly described minute, irregular, vertical ellipses. The tendrils apparently curve themselves spontaneously to the same side with the petioles; but from various causes, it was difficult to observe the movement of either the tendrils or petioles, in this and the two following species. The tendrils are so closely similar in all respects to those of *B. unguis*, that one description will suffice.

Bignonia unguis.—The young shoots revolve, but less regularly and less quickly than those of the last species. The stem twines imperfectly round a vertical stick, sometimes reversing its direction, in the same manner as described in so many leaf-climbers; and this plant though possessing tendrils, climbs to a certain extent like a leaf-climber. Each leaf consists of a petiole bearing a pair of leaflets, and terminates in a tendril, which is formed by the modification of three leaflets, and closely resembles that above figured (fig. 5). But it is a little larger, and in a young plant was about half an inch in length. It is curiously like the leg and foot of a small bird, with the hind toe cut off. The straight leg or tarsus is longer than the three toes, which are of equal length, and diverging, lie in the same plane. The toes terminate in sharp, hard claws, much curved downwards, like those on a bird's foot. The petiole of the leaf is sensitive to contact;

taneously from side to side; and on a very hot day, one made two elliptical revolutions, at an average rate of 2 hrs. 15 m. During these movements a coloured line, painted along the convex surface, appeared after a time on one side, then on the concave side, then on the opposite side, and lastly again on the convex side. The two branches of the same tendril have independent movements. After a tendril has spontaneously revolved for a time, it bends from the light towards the dark: I do not state this on my own authority, but on that of Mohl and Dutrochet. Mohl (p. 77) says that in a vine planted against a wall the tendrils point towards it, and in a vineyard generally more or less to the north.

The young internodes revolve spontaneously; but the movement is unusually slight. A shoot faced a window, and I traced its course on the glass during two perfectly calm and hot days. On one of these days it described, in the course of ten hours, a spire, representing two and a half ellipses. I also placed a bell-glass over a young Muscat grape in the hot-house, and it made each day three or four very small oval revolutions; the shoot moving less than half an inch from side to side. Had it not made at least three revolutions whilst the sky was uniformly overcast, I should have attributed this slight degree of movement to the varying action of the light. The extremity of the stem is more or less bent downwards, but it never reverses its curvature, as so generally occurs with twining plants.

the internodes and tendrils revolve together at the same rate; in Cissus, Cobæa, and most Passifloræ, the tendrils alone revolve; in other cases, as with *Lathyrus aphaca*, only the internodes move, carrying with them the motionless tendrils; and, lastly (and this is the fourth possible case), neither internodes nor tendrils spontaneously revolve, as with *Lathyrus grandiflorus* and *Ampelopsis*. In most Bignonias, Eccremocarpus, Mutisia, and the Fumariaceæ, the internodes, petioles and tendrils all move harmoniously together. In every case the conditions of life must be favourable in order that the different parts should act in a perfect manner.

Tendrils revolve by the curvature of their whole length, excepting the sensitive extremity and the base, which parts do not move, or move but little. The movement is of the same nature as that of the revolving internodes, and, from the observations of Sachs and H. de Vries, no doubt is due to the same cause, namely, the rapid growth of a longitudinal band, which travels round the tendril and successively bows each part to the opposite side. Hence, if a line be painted along that surface which happens at the time to be convex, the line becomes first lateral, then concave, then lateral, and ultimately again convex. This experiment can be tried only on the thicker tendrils, which are not affected by a thin crust of dried paint. The extremities are often slightly curved or hooked, and the curvature of this part is never reversed; in this respect they differ from the ex-

with a stick, do they not, like twining plants, spirally wind round it? One reason may be that they are in most cases so flexible and thin, that when brought into contact with any object, they would almost certainly yield and be dragged onwards by the revolving movement. Moreover, the sensitive extremities have no revolving power as far as I have observed, and could not by this means curl round a support. With twining plants, on the other hand, the extremity spontaneously bends more than any other part; and this is of high importance for the ascent of the plant, as may be seen on a windy day. It is, however, possible that the slow movement of the basal and stiffer parts of certain tendrils, which wind round sticks placed in their path, may be analogous to that of twining plants. But I hardly attended sufficiently to this point, and it would have been difficult to distinguish between a movement due to extremely dull irritability, from the arrestment of the lower part, whilst the upper part continued to move onwards.

Tendrils which are only three-fourths grown, and perhaps even at an earlier age, but not whilst extremely young, have the power of revolving and of grasping any object which they touch. These two capacities are generally acquired at about the same period, and both fail when the tendril is full grown. But in *Cobæa* and *Passiflora punctata* the tendrils begin to revolve in a useless manner, before they have become sensitive. In the Echinocystis they retain their sensitiveness for some time after they have ceased to

from branch to branch, and securely ramble over a wide, sun-lit surface.

The divisions containing twining plants, leaf-climbers, and tendril-bearers graduate to a certain extent into one another, and nearly all have the same remarkable power of spontaneously revolving. Does this gradation, it may be asked, indicate that plants belonging to one subdivision have actually passed during the lapse of ages, or can pass, from one state to the other? Has, for instance, any tendril-bearing plant assumed its present structure without having previously existed as a leaf-climber or a twiner? If we consider leaf-climbers alone, the idea that they were primordially twiners is forcibly suggested. The internodes of all, without exception, revolve in exactly the same manner as twiners; some few can still twine well, and many others in an imperfect manner. Several leaf-climbing genera are closely allied to other genera which are simple twiners. It should also be observed, that the possession of leaves with sensitive petioles, and with the consequent power of clasping an object, would be of comparatively little use to a plant, unless associated with revolving internodes, by which the leaves are brought into contact with a support; although no doubt a scrambling plant would be apt, as Professor Jaeger has remarked, to rest on other plants by its leaves. On the other hand, revolving internodes, without any other aid, suffice to give the power of climbing; so that it seems probable that leaf-climbers were in most cases at first twiners, and subse-

genus Mikania, there are leaf-climbing and twining species. The leaf-climbing species of Clematis are very closely allied to the tendril-bearing Naravelia. The Fumariaceæ include closely allied genera which are leaf-climbers and tendril-bearers. Lastly, a species of Bignonia is at the same time both a leaf-climber and a tendril-bearer; and other closely allied species are twiners.

Tendrils of another kind consist of modified flower-peduncles. In this case we likewise have many interesting transitional states. The common Vine (not to mention the *Cardiospermum*) gives us every possible gradation between a perfectly developed tendril and a flower-peduncle covered with flowers, yet furnished with a branch, forming the flower-tendril. When the latter itself bears a few flowers, as we know sometimes is the case, and still retains the power of clasping a support, we see an early condition of all those tendrils which have been formed by the modification of flower-peduncles.

According to Mohl and others, some tendrils consist of modified branches: I have not observed any such cases, and know nothing of their transitional states, but these have been fully described by Fritz Müller. The genus Lophospermum also shows us how such a transition is possible; for its branches spontaneously revolve and are sensitive to contact. Hence, if the leaves on some of the branches of the Lophospermum were to abort, these branches would be converted into true tendrils. Nor is there anything improbable

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